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INTERACTION OF SUCKLING-CALF BEHAVIOR, DAM'S MILK PRODUCTION AND CALF GROWTH

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Interaction of Suckling-Calf Behavior, Dam's Milk Production and Calf Growth" submitted by Jaime Alfonso Peschiera, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The suckling behavior of 46 calves was observed in June, July and August, 1965. The major study involved 40 Hereford cows with 20 purebred (HE) and 20 crossbred (XB) calves, each group having 10 males and 10 females. The results from the second observation and from the six extra cows and calves were not used. Purebreds averaged 3.1 and crossbreds 3.4 sucklings per day in June and 3.6 and 3.8, respectively, in August. The peak nursing times were early morning, noon and late afternoon.

Milk yield for the 46 cows was measured in July, August, September and October. The average 24-hour milk yield was 4.0 kg, with a range from 2.3 to 6.0 kg. The monthly average yields for dams with XB calves declined from 5.4, 4.0, 3.3 to 3.1 kg/day and those for dams with HE calves from 5.8, 4.1, 3.3 to 2.8 kg/day. The milk yield of the former was significantly ($P < 0.01$) higher in the later stages of lactation. The greater persistency of lactation of dams with XB calves was probably influenced by the higher frequency of nursing and heavier weights of their calves.

The males were heavier throughout the suckling period, but only significantly ($P < 0.05$) so at birth. The average daily gain (ADG) from birth to weaning for XB and HE calves was 0.69 and 0.65 kg respectively; the crossbreds gained consistently faster throughout the period and significantly ($P < 0.01$) so in the later stages, suggesting that they ate more or were more efficient or both.

Because all daily milk yield recordings were highly correlated with ADG ($r=0.40$ to 0.80), the use of only one measure of milk yield accounted for most of the variation when predicting ADG.

Percentages of milk constituents decreased initially, but then rose gradually until weaning. These percentages were poor predictors of ADG because of their low correlation with calf growth.

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INTRODUCTION

The growth of the calf until weaning depends to a large extent on the environment provided by the dam, or more specifically, on the milk production of the cow. Although milk production in beef cows has been studied and their milk yield determined, the influence of the calf on the milk production of its dam has not been fully explored.

The appetite of the calf is one of the factors that can influence milk production and the nursing behavior of calves should reflect variations in appetite. By observing the nursing behavior of calves with expected different growth potentials and measuring the milk yield of their dams, it should be possible to determine the kinds of interactions existing between cows and calves. The aims of this project were to study these interactions and some of the genetic and environmental factors influencing pre-weaning growth and milk production.

A greater knowledge of the factors involved in pre-weaning growth should permit a more efficient and intelligent use of selection and other genetic tools in attempting economic improvement in this phase of beef cattle production.

LITERATURE REVIEW

I. Suckling Behavior of the Young

The appetite of the calf could be an important factor influencing the milk production of the cow. Variations in appetite would be reflected in the suckling behavior, and specifically, in the number of sucklings per day and the time spent suckling.

There are three stages in the process of suckling: (i) massaging of the udder, the afferent excitation that causes the release of oxytocin; (ii) rapid suckling, the ejection and removal of milk from the udder; (iii) more vigorous massaging, more actual suckling although little milk is obtained (Donald, 1937b; Kon and Cowie, 1961).

Drewry, Brown and Honea (1959) observed that the average number of sucklings from dawn until dusk varied with age in Angus calves. In the first month of age the calves suckled 4.6 times per day, 4.8 in the third and 3.0 in the sixth. Night suckling was negligible. Walker (1962) carried out ten 24-hour observations between birth and weaning. The average number of nursings for purebred and crossbred calves was: 5.0, 4.4, 4.3, 4.2 and 3.7 times per day for the first five months of lactation. The intervals between sucklings tended to increase with age. Hutchison et al. (1962) found the average frequency of nursing in zebu cattle was 9.5 times in 24 hours in the first month and 5 to 6 times in the sixth month.

During the first month heavier and older calves suckling lighter milkers suckled more frequently and longer. However, in the sixth month the calves suckling heavier milkers suckled more frequently and longer (Drewry et al., 1959). Walker (1962) found crossbred dams suckled their

calves more frequently and for a shorter time than purebreds. Hutchison et al. (1962) reported calves suckled for an average period of 9.2 minutes, although total time spent suckling decreased with age of calf.

Hutchison et al. (1962) reported suckling intensity spread evenly over 24 hours during the first month, but thereafter suckling became increasingly confined to nighttime while the cattle were yarded. Four peak periods were detected in the suckling pattern: 4:00 to 5:00 AM, very pronounced and consistent; 8:00 to 10:00 AM, common during the first three months; 1:00 to 3:00 PM, very pronounced, but tending to drift earlier; and 11:00 to 12:00 PM, moderately pronounced and consistent. Walker (1962) observed somewhat similar but more extensive periods of nursing: 4:00 to 6:00 AM, 9:00 to 12:00 AM, 3:00 to 6:00 PM, and 10:30 PM to 1:00 AM.

II. Determination of Milk Yield in Beef Cattle

Milk ejection is stimulated by the suckling of the calf. Oxytocin and vasopressin are released due to the suckling stimulus. These hormones cause the contraction of the myoepithelial fibres of the udder, forcing milk into the ducts and cisterns (Ely and Petersen, 1941; Espe, 1946; Kon and Cowie, 1961; Smith, 1959; Whittlestone, 1962). Similarly, dairy cows are conditioned to respond to the stimulus of the milking procedure which causes the release of the two hormones.

Because the action of oxytocin is essential for milk let-down, milk yield in nursing beef cows has been estimated by weighing the calf before and after nursing or by injecting oxytocin and removing the milk manually (Gleddie, 1965). A description of a manual technique was given by Anthony et al. (1959) and Gleddie (1965).

The technique of weighing the calf before and after suckling measures only how much milk the calf consumes rather than the actual milk yield (Drewry et al., 1959; Gifford, 1949, 1953). Normal milk let-down may be inhibited in before-and-after weighing due to the excessive handling of the animals. Therefore, manual methods should give closer estimates of milk production (Coombe, Wardrop amd Tribe, 1960).

Oxytocin has also been used to estimate the milk yield of ewes. Manual methods gave significantly ($P < 0.01$) higher estimates of milk production than the technique of weighing the lamb before and after suckling (Coombe et al., 1960; Moore, 1962).

III. Determining Factors in Milk Production

A. Hereditary

There are large differences in milk yield between dairy and beef cows as well as among the breeds of cows in these two types of cattle. Several workers have measured the milk yield of beef cows and much of the work done has dealt with the Hereford, Aberdeen-Angus and Shorthorn breeds.

The monthly milk yield averages of Hereford cows over a 240-day period were: 3.9, 3.5, 3.3, 2.7, 2.8, 2.1, 2.1 and 1.9 kg per day (Gifford, 1949). Neville (1962) determined the yields of Hereford cows over a 240-day period. The lactation average was 4.4 kg/day with a range from 0.8 to 8.0 kg/day. Gifford (1953) found the milk yield of Hereford cows covered a range from 0.6 to 5.3 kg/day. The average milk yield of Hereford cows milked by Klett, Mason and Riggs (1965), using oxytocin, was 2.9 kg/day.

The average milk yield of Angus cows measured by Cole and Johansson (1933) was 5.2 kg/day. These cows were handled as dairy cows. Walker (1963) determined the milk yield of Angus heifers over 180 days. The average

daily yield was 5.5 kg with a range from 4.5 to 6.4 kg. Drewry et al. (1959) reported an average daily milk yield for Angus cows of 6.4, 7.3 and 4.1 kg for the first, third and sixth month of lactation, respectively. In Angus cows milked out with oxytocin the average milk yield was 3.9 kg/ day (Klett et al., 1965).

In Shorthorn cows the average yield over a 252-day period was 8.0 kg/day; the highest monthly average was 10.3 kg/day and the yield for the last month was 6.2 kg/day (Dawson, Cook and Knapp, 1960).

Walker (1963) measured the milk yield of dairy-beef crossbred heifers. The average yield for the Hereford x Angus crosses was 5.8 kg/ day with a range from 4.2 to 7.6 kg/day; that of the Angus x Jersey crosses was 7.9 kg/day with a range from 6.2 to 9.4 kg/day; and the Angus x Holstein crosses averaged 5.8 kg/day with a range from 4.5 to 7.1 kg/day. All these average yields were calculated over a 180-day period.

Gleddie (1965) found that the effect of breed of dam on milk yield was highly significant ($P < 0.01$). The breeds of cows compared were Hereford, Angus and Galloway and their average daily yield over a 180-day period was 5.2, 8.4 and 7.8 kg, respectively. It should be noted that the differences in milk yield reported by various workers could be due to differences in plane of nutrition or other environmental factors.

The heritability of milk yield has been estimated using different breeds of cattle under different environments (Table 1). Most of the estimates in dairy cows varied from about 0.45 (Rendel et al., 1957) to about 0.27 (Mahadevan, 1951a; Mason, 1964). Christian, Hauser and Chapman (1965) reported an average of 0.48 (range: 0.25 to 0.75) in beef cattle.

These are some of the factors that might affect the estimates of heritability of milk yield: the method of calculation (daughter-dam

regressions or paternal half-sib correlations), level of production of the herd, lactation number and whether or not twins were used for the estimates (Christian et al., 1965; Johansson, 1958; VanVleck and Bradford, 1964, 1966; Watson, 1961).

Table 1. Heritability and repeatability of milk yield

Field data	Heritability[a]	Repeatability[a]
Various dairy breeds (USA)	0.25	
Ayrshires (USA)	0.31	
Jerseys (USA)	0.20	0.41
Six dairy breeds (GB)	0.43	0.48
Ayrshires (GB)	0.31	0.46
Red and White cattle (Sweden)	0.39	0.43
Friesians (Holland)	0.35	

a daughter-dam regression

Source: Johansson (1958)

Venge (1963) reported a heritability of 0.26 for rate of milking and that genetic differences are more pronounced from the third to the sixth month of lactation. Donald (1960) found that rate of milking ranged from under 0.9 kg per minute to over 3.2 kg per minute. There was a significant relationship between rate of milking and total lactation yield; it was also correlated with persistency of lactation (Donald, 1960; Smith, 1959; Venge, 1963; Whittlestone, 1962).

B. Environmental

The shape of the lactation curves of beef cows is different from that of dairy cows; the maximum yield is obtained during the first month and it declines throughout lactation. The milk consumption of the young, or more specifically, the appetite of the calf, has an effect on the milk production of the cow. There is evidence that the maximum milk production normally obtained during the first six weeks of lactation is affected by the capacity of the young calves to consume the milk (Brumby, Walker and Gallagher, 1963; Gifford, 1949, 1953; Klett et al. 1965; Walker, 1963). If milk is not completely removed from the udder, the production of high producing cows levels off at 5.4 to 6.8 kg daily (Gifford, 1949). Heavier milkers among Angus cows had some milk remaining after suckling during the first month of lactation (Drewry et al., 1959; Gerlaugh, Kunkle and Rife, 1951). Elliot (1961) found that increasing residual milk by 0.5 kg in each half udder for a 39-day period caused a 15% decrease in both milk and butterfat yields. There was a 12% increase in milk yield when cows were milked three times a day instead of two.

Brumby et al. (1963) found that the limit of a young calf's capability appears to be in excess of 7.3 kg/day. Gifford (1953) reported that the average daily consumption of calves from three studies was 10.1, 8.5 and 7.5 kg.

The effect of the young on the milk production of the dam is apparent in sheep nursing twins vs. singles. Ewes nursing twins gave significantly higher milk yields than those nursing singles (Alexander and Davies, 1959; Barnicoat, Logan and Grant, 1949 a,b; Barnicoat et al., 1956; Davies, 1963; Doney and Munro, 1962; Gardner and Hogue, 1964; Sacker and Trail, 1966; Slen, Clark and Hironaka, 1963). However, Burris and Baugus (1955) found

that the milk yield of ewes suckling twins was similar to those nursing singles, but these results are questionable as the number of ewes was very small.

Two possibilities have been considered to explain this phenomenon. Either the pressure created by the accumulated milk in the ewes nursing singles reduces the rate of milk secretion or the external stimulation of ewes nursing twins is greater (Alexander and Davies, 1959; Davies, 1963; Gardner and Hogue, 1964; Sacker and Trail, 1966; Slen et al., 1963).

Davies (1963) found that ewes nursing single crossbred lambs gave a significantly higher milk yield than those nursing purebreds. This was not the case with twins. It is suggested that the more rapid withdrawal of milk by crossbreds influenced milk production of the ewe and that the milk production of the ewes nursing crossbred twins was insufficient to meet their requirements.

Some of the other environmental factors affecting milk yield and persistency of lactation are: age of cow, pregnancy, number of previous lactations and length of preceding calving interval (Drewry et al., 1959; Gaines and Davidson, 1926; Gifford, 1953; Mahadevan, 1951a; Rollins and Guilbert, 1954).

C. Physiological

Prolactin (lactogen), somatotrophin, adrenocorticotrophin, thyroid stimulating hormone and gonadotrophin are needed for normal lactation (Espe, 1946; Kon and Cowie, 1961; Smith, 1959; Whittlestone, 1962).

Lactation is maintained by the stimuli of suckling which cause a release of oxytocin (secreted by the neurohypophysis) which in turn acts on the adenohypophysis to release lactogen, the hormone mainly responsible

for milk secretion. Another mechanism by which suckling (or milking) could stimulate milk secretion is a humoral feedback to the adenohypophysis resulting from the depletion of galactopoietic hormones from the blood when the evacuated alveoli begin rapid secretory activity (Kon and Cowie, 1961; Smith, 1959; Whittlestone, 1962). Suckling (or milking) also reduces the pressure on the secretory epithelium and the surrounding blood capillaries and so prevents a decline in secretory intensity and, consequently, the involution of the mammary gland (Turner, 1955; Wheelock, Rook and Hood, 1965).

IV. Growth of the Offspring

A. Influence of maternal environment

The performance and growth of the offspring throughout the suckling period depend to a great extent on the environment provided by the dam; the most important factor in this environment is her milk production (Rollins and Guilbert, 1954; Walker, 1963). In several studies the milk production of the dam was the most important factor in calf growth from birth to weaning (Damon et al., 1961; Gerlaugh et al., 1951; Gleddie, 1965; Koch and Clark, 1955a).

Several workers have established a fairly high correlation between average daily gain from birth to weaning and milk yield (Table 2). Brumby et al. (1963) reported a correlation of 0.7 between average daily gain of the calf and milk yield of the dam. Lampkin and Lampkin (1960), working with zebu cattle, found a highly significant ($P < 0.01$) correlation of 0.78 in male calves and 0.64 in females, between growth of calf and milk consumption.

Highly significant ($P < 0.01$) correlations ranging from 0.67 to 0.81

between milk yield and calf weights at different stages were detected in Angus but not in Hereford cattle (Klett et al., 1965). Neville (1962) reported a correlation of 0.81 between 240-day weight of calf and milk yield; Gleddie (1965) determined a correlation of 0.85 between 180-day weaning weight and yield. These correlations are higher than those of 0.60, 0.71, 0.52, 0.35, 0.19, 0.24, 0.39 and 0.57 found by Gifford (1953) between daily milk yield and body weight for the first eight months of age, respectively. Lampkin and Lampkin (1960) reported significant correlations of 0.80 in males and 0.65 in females between weaning weight and milk consumption.

Table 2. Correlations between monthly average milk yield per day and partial average daily gain of calves

Author	Age of calf (months)					
	1st	2nd	3rd	4th	6th	8th
Drewry et al. (1959)	-0.15		0.35		0.48	
Gifford (1949)	0.60	0.71	0.52	0.35		
Gleddie (1965)		0.62	0.81	0.83	0.82	
Neville (1962)		0.74		0.63	0.59	0.66

Similar studies have been performed with sheep and pigs. Correlations between milk yield and growth rates in sheep ranged from 0.64 to 0.83 (Barnicoat et al., 1956; Burris and Baugus, 1955). Salmon - Legagneur and Aumaitre (1962) reported a decrease in correlations from 0.64 to 0.09 between ADG in pigs and milk production from the second to the seventh week of age.

B. Genetical factors influencing growth

The estimates of heritability of average daily gain (ADG), weight per day of age (wt/day) and weaning weight cover a fairly wide range (Table 3). Koch and Clark (1955b) determined heritability estimates for ADG which ranged from 0.07 ± 0.06 to 0.17 ± 0.12. Heritabilities for weaning weight ranged from 0.11 ± 0.06 to 0.25 ± 0.11. Warwick (1958, 1960) reported a heritability of 0.30 for weaning weight, averaged from several estimates with a range from -0.13 to 1.0. The estimates of heritability vary with the methods of calculation used; higher estimates are obtained with regressions on the sire than with those on the dam.

The repeatability of ADG ranges from 0.34 to 0.38 and that of weaning weight from 0.34 to 0.46 (Botkin and Whatley, 1953; Koch and Clark, 1955a; Minyard and Dinkel, 1965).

Table 3. Heritability of ADG, wt/day and weaning weight in cattle

Author	ADG	wt/day	weaning weight
Brinks et al. (1964)	0.40		0.43
Brumby et al. (1963)	0.38 ± 0.10		
Koch and Clark (1955a)	0.21		0.24
Marlowe and Vogt (1965)	0.34 ± 0.04		
Mason (1964)		0.27 ± 0.11	
Minyard and Dinkel (1965)			0.32 ± 0.07
Soller, Shilo and Bar-Anan (1966)		0.33 ± 0.10	
Swiger (1961)			0.24 ± 0.11

The ADG from birth to weaning in Hereford cattle ranged from 0.5 to 0.7 kg/day (Gifford, 1949, 1953; Gleddie, 1965).

Swiger (1961) found large positive genetic correlations between gains made in different periods during the first year. On the other hand, Brinks et al. (1964) reported small negative correlations between gain from birth to weaning and gain from weaning to 12 months and between weaning weight and gain from weaning to 12 months.

Because of the difference in growth response in the pre-weaning and post-weaning environments, some workers have postulated that there is a negative genetic relationship between maternal environment and post-weaning gain, i.e., that different sets of genes condition the response of calves in pre- and post-weaning environments (Koch and Clark, 1955a,b,c; Warwick, 1958). However, Gifford (1953) reported high correlations of 0.82, 0.69, 0.53 and 0.55 between post-weaning gains and milk yield for the 8th, 12th, 24th and 36th months of age, respectively.

Heterosis or hybrid vigor for weaning weight, ADG and wt/day has been observed in crosses of two or more breeds of cattle. The crosses involving the more widely divergent genetic sources, such as Hereford and Brahman or Charolais breeds, yielded higher estimates of specific combining ability (Damon et al., 1959; Damon et al., 1961; Warwick, 1960).

Gaines et al. (1966) proposed that increased performance of crossbred calves could be due to a favorable interaction of maternal effects and the crossbred calves, although heterosis in the crossbred calf seemed a more likely explanation. Heterosis was observed in crosses between British breeds but not in those involving Hereford dams (Table 4). Gregory et al. (1965) found significant differences between reciprocal crosses of British breeds when the Hereford dams were involved. They concluded the heterosis observed, when the reciprocal crosses were compared with the parental breeds, was a characteristic of the breeds used rather

Table 4. Heterosis in ADG and weaning weight in crosses between British beef breeds

Type of mating			Number	ADG (kg/day)[a]			weaning weight (kg)[b]		
male		female	of calves	calves	midparent	difference	calves	midparent	difference
A[1]	x	A	40	0.76			188		
H[2]	x	H	36	0.70			176		
S[3]	x	S	30	0.78			190		
H	x	A	21	0.81	0.74	0.07*	196	182	14**
S	x	A	21	0.84	0.77	0.07*	202	189	13**
A	x	H	22	0.73	0.74	-0.01	182	182	0
S	x	H	21	0.67	0.74	-0.07*	173	183	-10**
A	x	S	21	0.82	0.77	0.05*	199	189	10**
H	x	S	17	0.81	0.74	0.07*	201	183	18**

a adjusted for sex and age of dam
b 200-day weight; adjusted for age of dam and sex and age of calf
1 Angus; 2 Hereford; 3 Shorthorn
* significant at $P \leq 0.05$
** significant at $P \leq 0.01$

Source: Gaines et al. (1966)

than of specific sires (Table 5).

Lawson and Peters (1964) reported that average weaning weights of reciprocal crosses between the Hereford and Highland breeds were greater than those of parental breeds by 9.2% (6.0% over the Hereford and 12.6% over the Highland). They obtained significant differences in weaning weight when the crosses were compared (Table 6).

Damon et al. (1959) found a difference of 19.5 kg in weaning weight between Hereford x Angus (sire x dam) and Angus x Hereford calves. Lopez et al. (1963) reports a difference of 27.4 kg in weaning weight between Hereford x Angus and Angus x Hereford calves, 6.4 kg between Shorthorn x Angus and Angus x Shorthorn calves and 23.4 kg between Hereford x Shorthorn and Shorthorn x Hereford calves. All six differences from midparent values were positive and ranged from 1.7 kg to 30.8 kg.

Gerlaugh et al. (1951) determined a significant difference of 24.1 kg between purebred Angus and Hereford calves at weaning. The crossbreds (Hereford x Angus and Angus x Hereford) were 20.7 kg significantly heavier than the purebreds (Angus and Hereford) and the Hereford x Angus were 17.4 kg significantly heavier than the Angus x Hereford crosses.

V. Importance of Milk Composition

The percentage of butterfat, protein, solids-not-fat (SNF) and total solids (TS) in milk declines progressively from the onset of lactation to the end of the third month, after which a gradual increase is indicated. Longley and Rennie (1964) reported positive phenotypic correlations between all milk constituents. Rook and Campling (1965) detected a decrease in butterfat throughout lactation although it increased towards the end. There was also a decrease in SNF and protein until the fifth week of lactation,

Table 5. Heterosis in ADG and weaning weight in crosses between the Hereford, Angus and Shorthorn breeds

Type of mating[a]	Number of calves	ADG (kg/day)			weaning weight (kg)[b]		
		calves	midparent	difference	calves	midparent	difference
A[1] x A	115	0.806			190.6		
H[2] x H	118	0.774			190.4		
S[3] x S	125	0.781			189.0		
H x A and A x H	126	0.834	0.790	.044 ± .009**	200.4	190.4	10.0 ± 1.95**
H x S and S x H	140	0.822	0.778	.044 ± .009**	200.5	189.7	10.8 ± 1.86**
A x S and S x A	127	0.820	0.794	.026 ± .009**	195.6	189.8	5.8 ± 1.95**
		calves	superior parent	difference	calves	superior parent	difference
H x A and A x H	126	0.834	0.806(A)	.028 ± .009**	200.4	190.6	9.8 ± 1.95**
H x S and S x H	140	0.822	0.774(H)	.048 ± .009**	200.5	190.4	10.1 ± 1.86**
A x S and S x A	127	0.820	0.806(A)	.014 ± .009	195.6	190.6	5.0 ± 1.95*
		first[4]	second[5]	difference	first	second	difference
(HxA)[4] minus (AxH)[5]	66 + 60	0.865	0.803	.062 ± .014**	206.8	193.9	12.9 ± 3.10**
(HxS) minus (SxH)	68 + 72	0.854	0.790	.064 ± .014**	207.5	193.5	14.0 ± 3.01**
(AxS) minus (SxA)	62 + 65	0.826	0.814	.012 ± .015	196.8	194.4	2.4 ± 3.20

a sire x dam
b 200-day weight; adjusted for age of dam and age of calf
1 A, Angus; 2 H, Hereford; 3 S, Shorthorn; 4 first reciprocal cross; 5 second reciprocal cross
* significant at $P \leq 0.05$
** significant at $P \leq 0.01$
Source: Gregory et al. (1965)

Table 6. Heterosis in weaning weight of reciprocal crosses between the Hereford and Highland breeds

Type of mating[a]	weaning weight (kg)	difference (kg)
HE x HE[1]	164 $\pm$ 2.5	
HI x HI[2]	154 $\pm$ 3.0	
HE x HI	175 $\pm$ 3.2	
HI x HE	172 $\pm$ 2.7	
(HE) minus (HI)		9.6*
(HI x HE) minus (HI)		17.8**
(HE x HI) minus (HI)		20.9**
(HE x HI) minus (HE)		11.3*
(HI x HE) minus (HE)		8.2*

a sire x dam
1 Hereford; 2 Highland
* significant at $P < 0.05$
** significant at $P < 0.01$

Source: Lawson and Peters (1964)

no change until the tenth and then a gradual rise with a marked increase in late lactation. The concentration of the major constituents in milk tends to decrease from lactation to lactation. Gleddie (1965), working with beef cows, found that the percentage of protein, SNF and TS decreased until the second month of lactation and then increased until the end. Percent butterfat in milk increased from the beginning with a sharp increase in late lactation.

Gifford (1953) reported a range of 6.4 to 40.2 kg of butterfat over a 240-day period in a herd of Angus and Hereford cows; the highest producing Hereford gave 33.8 kg of butterfat over the lactation period. Dawson et al. (1960) reported 3.98% butterfat in milk for Shorthorn cows. Klett et al. (1965) found the average butterfat percentage in milk for Angus cows was 3.67%and 3.35% for Hereford cows. Gleddie (1965) reported the average percent butterfat, protein and SNF were 3.9%, 3.4% and 9.0% for Hereford and 4.0%, 3.4% and 9.1% for Angus cows, respectively.

The heritability estimates for percent butterfat in milk ranged from 0.43 to 0.81 when a regression of daughters on dams was used (Johansson, 1958; Mason, 1964; Rendel et al. 1957; Watson, 1961).

There were low non-significant correlations between major milk constituents and growth of calf (Gleddie, 1965; Klett et al. 1965). Gifford (1953) reported low significant correlations between total butterfat production and body weight for the first four months.

In sheep, there was no significant relationship between butterfat yield and growth rate of lambs (Barnicoat et al. 1956). Percent dry matter, butterfat and caloric value of the milk were significantly ($P < 0.05$) higher for ewes suckling twin lambs (Gardner and Hogue, 1964).

EXPERIMENTAL

I. Objectives

The present project was undertaken to study:

1) the nursing behavior of the calf and its relation to calf growth and milk yield of the dam,
2) the influence of the calf on the milk production of the dam, and
3) the relationship of milk yield and composition to calf growth.

II. Materials and Methods

A. Experimental animals

Forty Hereford cows and their calves were used in this study; the cows were part of the University of Alberta beef research herd. A complete description of the breeding and general management of the herd was given by Berg (1962, 1966).

Half of the calves were from Hereford sires, and the sires of the other half were of the following breeds or crosses: Charolais, Charolais x Galloway, Charolais x Angus, Galloway x Charolais-Angus and Brown Swiss. There were 10 males and 10 females in both the Hereford (HE) and crossbred (XB) groups of calves. All the dams calved in approximately a month's period, from April 1st to May 1st, 1965. An attempt was made to pair purebred and crossbred calves of the same sex according to date of birth (Appendix, Table 1).

B. Observation of calf behavior

The suckling behavior of the calves was observed three times during the summer of 1965. A field of 60 acres of improved grass was used for all the observations.

The first observation took place on June 24-25, from 11:00 AM to 9:40 PM, 11:45 PM to 12:30 AM and from 3:30 AM to 11:00 AM. On July 29-30 the cows and calves were watched from 2:45 PM to 9:15 PM and from 4:25 AM to 2:45 PM. The last observation was on August 31-September 1 from 8:50 AM until 9:15 PM, 11:20 PM to 12:10 AM and from 4:25 AM to 8:50 AM.

To identify the animals, large numbers were painted on both sides of the cows and calves using a black dye. Two observers kept a complete log of the number of nursings of each calf and of the time of day when each nursing started. Binoculars were used for daytime watching and a flashlight and a station-wagon were used at night to assist in observing the nursings.

Six Charolais x Angus crossbred cows and their calves, 3 males and 3 females, were also observed and nursings recorded at the same time as those of the Hereford cows.

C. Milking procedure

The same forty-six cows as above were milked four times during the summer. The first milking was performed on July 1-2, the second on August 3-4, the third on September 3-4 and the fourth on October 6-8. These dates correspond approximately with the 75th, 105th, 135th and 168th day of lactation, respectively. The average age of the Hereford cows was 4.7 ± 1.6 years, with a range from 2 to 9 years (Appendix, Table 1).

The afternoon before each milking the calves were separated from their dams and the cows were confined (in a commercial stock squeeze) and milked out. Oxytocin was injected (20 IU) intravenously to stimulate the ejection of milk. A portable milker was used and operated at 12 to 16

inches vacuum and 60 to 70 pulsations per minute. A chronometer was used to determine the total time it took to milk each of the cows. After hand stripping, the cows, separated from their calves, were allowed access to feed and water overnight. The next morning, 12 hours later, the cows were milked again in the same order as in the previous milking. The four quarters of the udder were milked and the milk weighed using a spring balance. The 12-hour milk production was multiplied by 2 to estimate 24-hour yield. For analysis of milk composition, eight-ounce samples were taken and immediately placed in a portable ice cooler from which they were transferred to a refrigerator. No preservatives were used. One of the cows had only three functional quarters and no adjustments were made to her milk yield.

The milking procedure in October differed from the previous ones in that the milk was removed by the use of teat tubes and 6-hour production was multiplied by 4 to estimate 24-hour yield.

D. Weighing of cows and calves

The cows were weighed in March, June and October, and the weight change from March to October was calculated.

The calves were weighed five times during the summer: at birth, on July 8, August 10, September 11 and October 12. The last weight was taken as the weaning weight of the calf.

E. Chemical analysis of milk

The rapid detergent method (first action) for raw milk was used for determining the percentage of butterfat in the milk (AOAC, 1960).

Protein determination was by the dye-binding procedure (Udy, 1956).

Solids-not-fat (SNF) were determined by the plastic bead method of

Golding (1964).

Total solids (TS) were calculated by adding fat and solids-not-fat determinations.

F. Statistical analysis

All the measurements of weight were taken in pounds but the results from this project are all in the metrical system. A conversion factor of 2.2 lb equal to 1 kg was used.

The volumetric measurements (ml) from the fourth milking (October) were converted to kilograms by using a specific gravity for milk of 1.027.

An IBM 7040 computer was used to calculate analyses of variance and covariance, correlations and multiple regressions. The computations followed procedures outlined by Steel and Torrie (1960).

III. Results and Discussion

A. Nursing behavior of the calves

The observations made during the second period on July 29-30 were not included in the analyses of data. Thick fog during the night and early morning of the second day prevented the recording of a large number of sucklings. For this reason it was deemed that the data for the second set of observations were incomplete.

The data on the behavior of the six crossbred calves born of crossbred dams were obtained for comparison purposes only and were not analysed statistically.

The results from the June observations show three more or less defined 'peaks' in the nursing pattern: at approximately 7:00 AM, at noon, and less clearly defined at 7:00 PM (Fig. 1). No nursing was

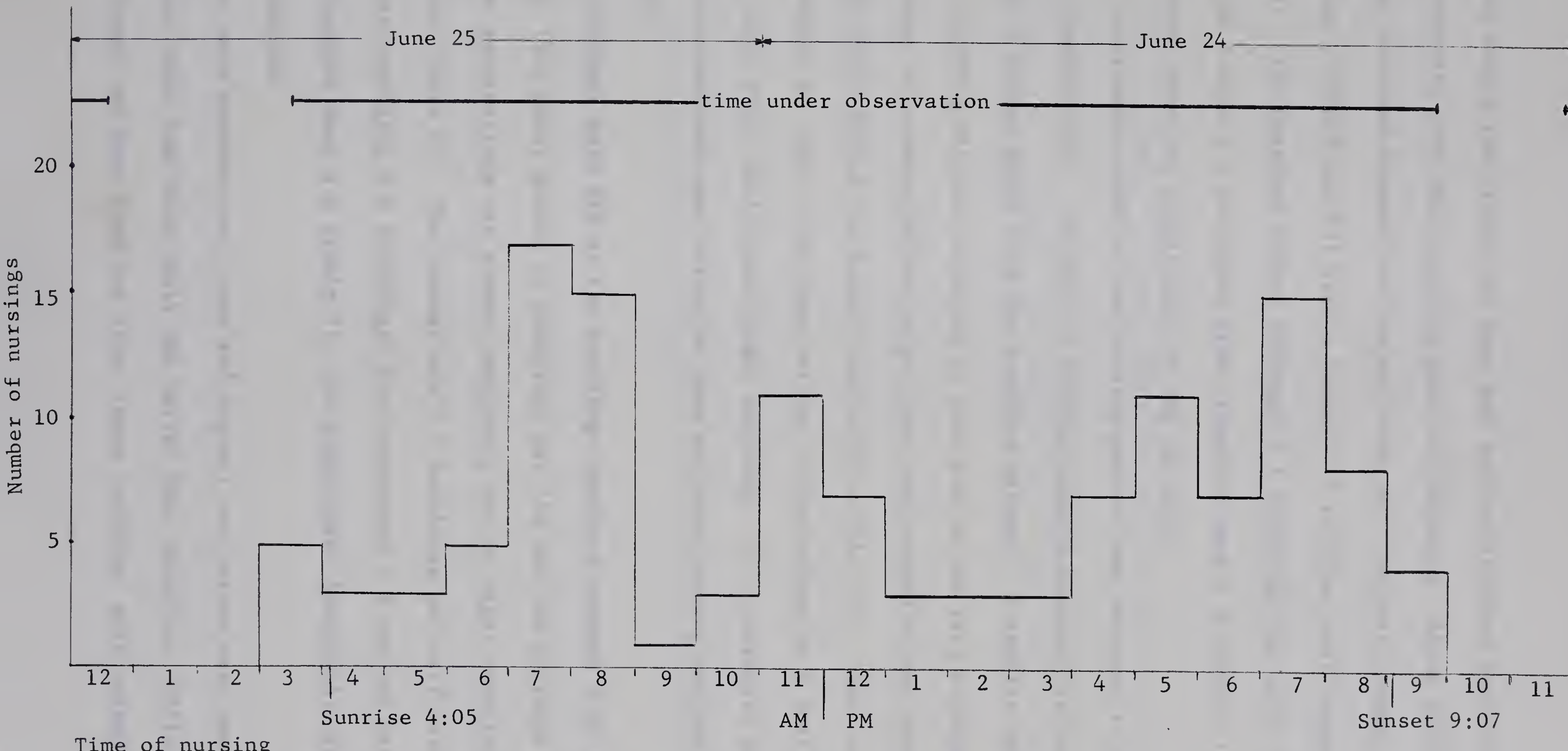
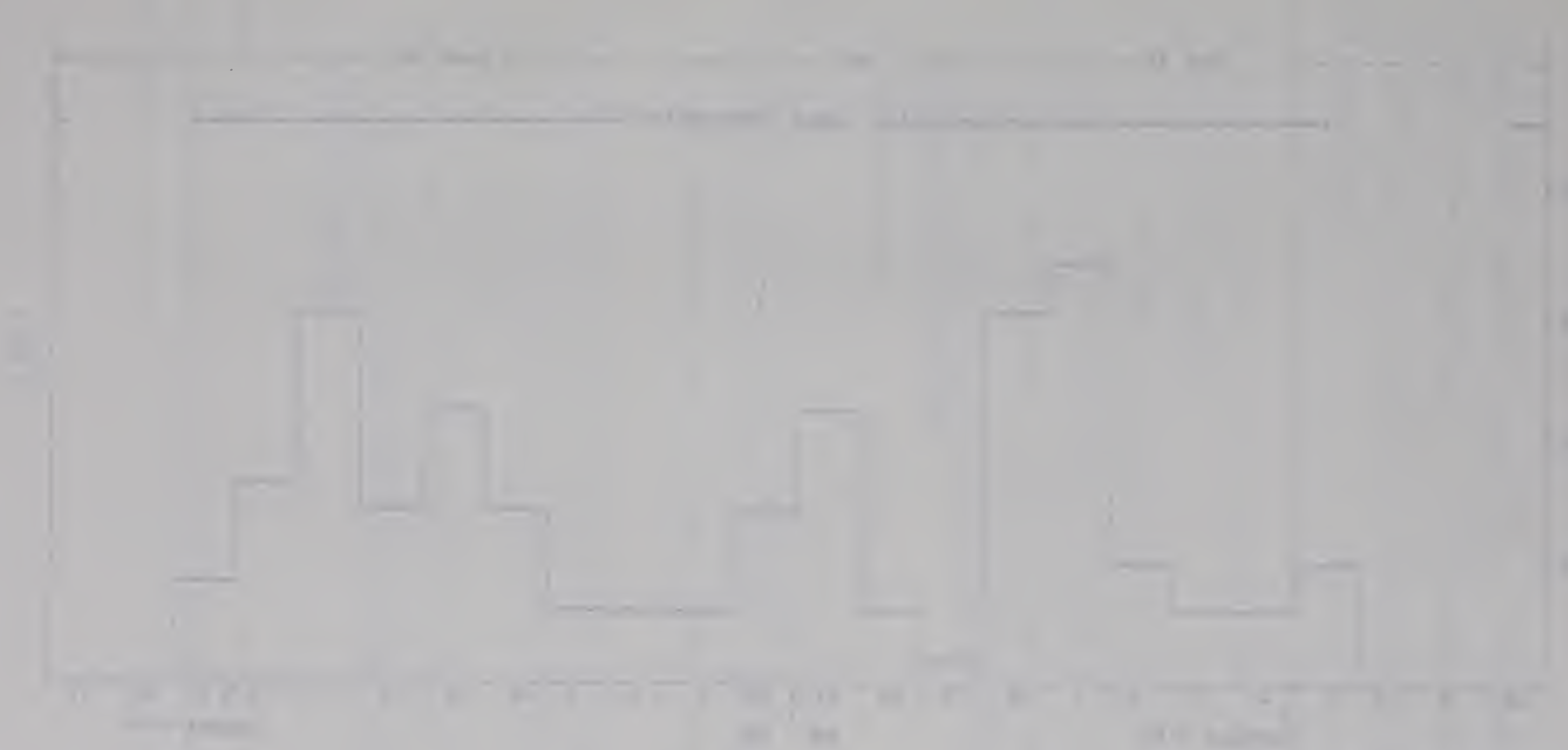


Figure 1. Nursing pattern corresponding to the observations of June 24-25



observed during the night; the cows had settled all over the field, and it is possible that some nursings were not detected. About 66% of the nursings occurred between 6:00 AM and 6:00 PM. The total number of sucklings recorded was 131 with a range of 2 to 5 per calf (Appendix, Table 2). The Hereford calves averaged 3.1 sucklings per calf, the crossbred calves 3.4 and those from crossbred dams 3.5 (Table 7). These differences were not significant at the 5% level.

A noticeable shift in the nursing pattern was detected in the August observations. The peak in morning nursing occurred at around 5:00 AM, a 2-hour shift from the previous pattern. A similar shift to earlier nursing was also detected at noon and in the late afternoon. This change in nursing pattern might have been caused by the shorter daylight hours during the August observations (Fig. 2). Some nursing was observed at night. The cows settled in two groups in a small area of the field which facilitated night watching. It is possible that the observers disturbed some calves or cows and some nursing was indirectly induced.

In August only 51% of the sucklings occurred between 6:00 AM and 6:00 PM. The total number of sucklings was 146 and the increase over the June observations was almost completely due to night suckling (Appendix, Table 2). The average was 3.7 sucklings per calf, with the Herefords averaging 3.6 sucklings, the crossbreds 3.8 and the six calves from crossbred dams 3.8 (Table 7). No significant ($P \leq 0.05$) differences were detected.

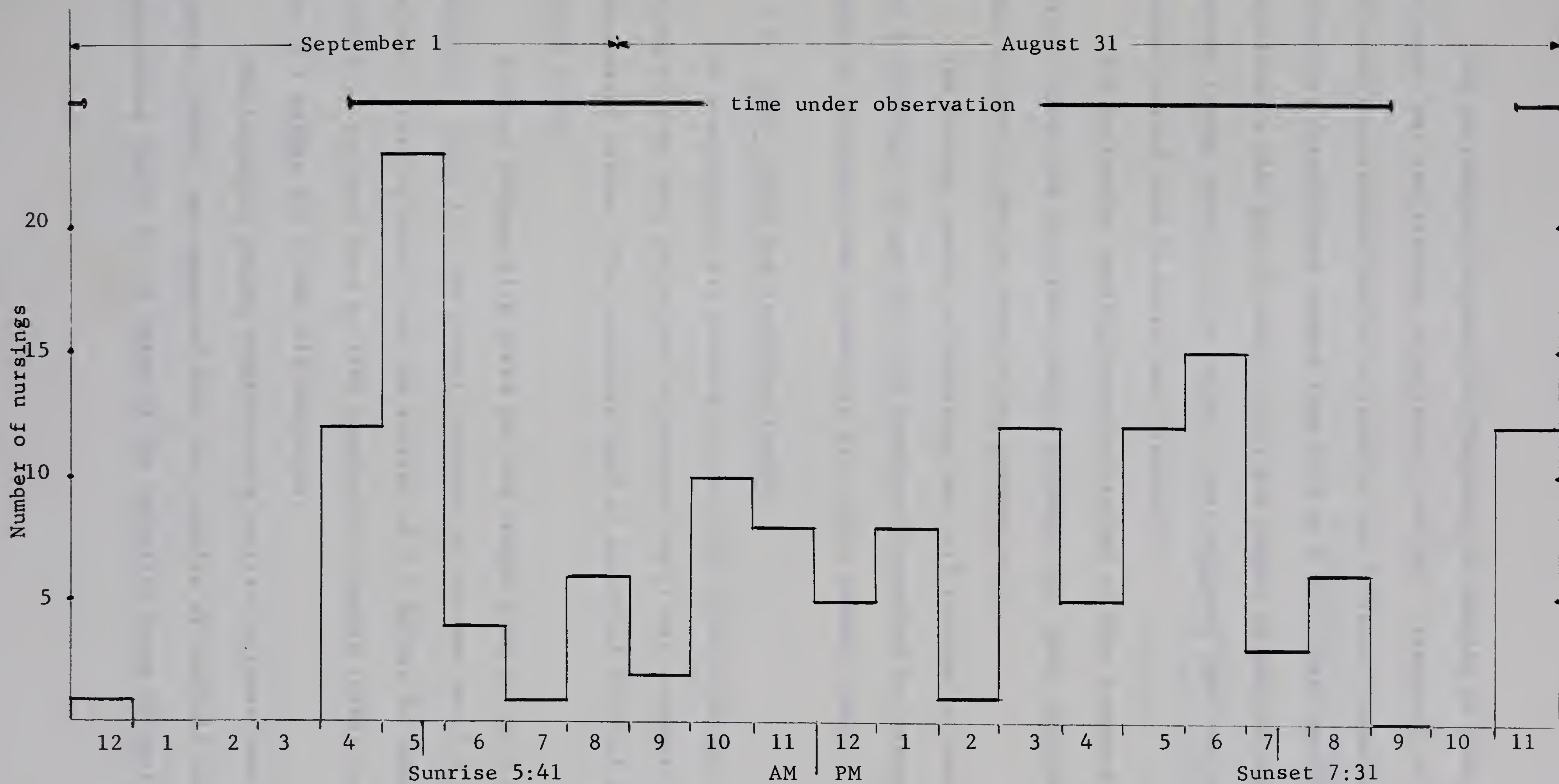
In both observations (June and August) two calves were seen 'robbing' milk from other dams when their own calves were suckling. While the calves nursed their own dams from the side, those 'robbing' milk nursed from behind.

Table 7. Means and standard deviations of frequency of nursing for the breed-sex groups of calves

Frequency of nursing	Groups of calves[1]								
	HE-M	HE-F	XB-M	XB-F	HE	XB	M	F	Total
June									
Mean	3.2	3.0	3.4	3.5	3.1	3.4	3.3	3.3	3.3
SD[2]	0.9	0.7	1.0	0.9	0.8	0.9	0.9	0.8	0.8
August-September									
Mean	3.7	3.4	3.7	3.8	3.6	3.8	3.7	3.6	3.7
SD	0.9	0.7	0.9	1.1	0.8	1.0	0.9	0.9	0.9

1 HE-M, Hereford-males; HE-F, Hereford-females; XB-M, crossbred-males; XB-F, crossbred-females; HE, Hereford; XB, crossbred; M, male; F, female; Total, all 40 calves

2 SD, standard deviation



Time of nursing

Figure 2. Nursing pattern corresponding to the observations of August 31-September 1

The correlation between the frequency of nursing in June and that in August was low although significant (r=0.36). Frequency of nursing was poorly correlated with milk yield at the different stages of lactation; correlations ranged from 0.13 to 0.35. There were significant correlations with age of calf (-0.51) and weight of calf at different periods (range from -0.37 to -0.45). This suggests that the younger and lighter calves tend to nurse more frequently.

The pattern of nursing found is similar to that reported by Walker (1962) and Hutchison (1962), although the 'peak' periods of nursing seem to cover a shorter time in the present study.

The average number of sucklings per calf recorded is smaller than the 4 sucklings or more per calf previously reported for calves from Angus or crossbred cows (Drewry et al., 1959; Walker, 1962).

B. Milk yields and lactation trends

No observations are missing in the first three milkings, but four of the 40 cows were not milked in October and it was necessary to estimate the missing values. The procedure used is described by Steel and Torrie (1960).

Average 24-hour milk yield per cow ranged from 2.3 to 6.0 kg (Appendix, Table 3). The overall average for 40 cows was 4.0 kg of milk per day. This is lower than the average of 5.2 kg/day for mature Herefords from the same herd in 1964 reported by Gleddie (1965), but higher than 3.7 kg/day for 2-year old Herefords.

The lactation trends observed were similar to those described by Gleddie (1965), who suggested that the appetite of the calf could be a determining factor in the shape of the lactation curve of beef cows (Fig. 3).

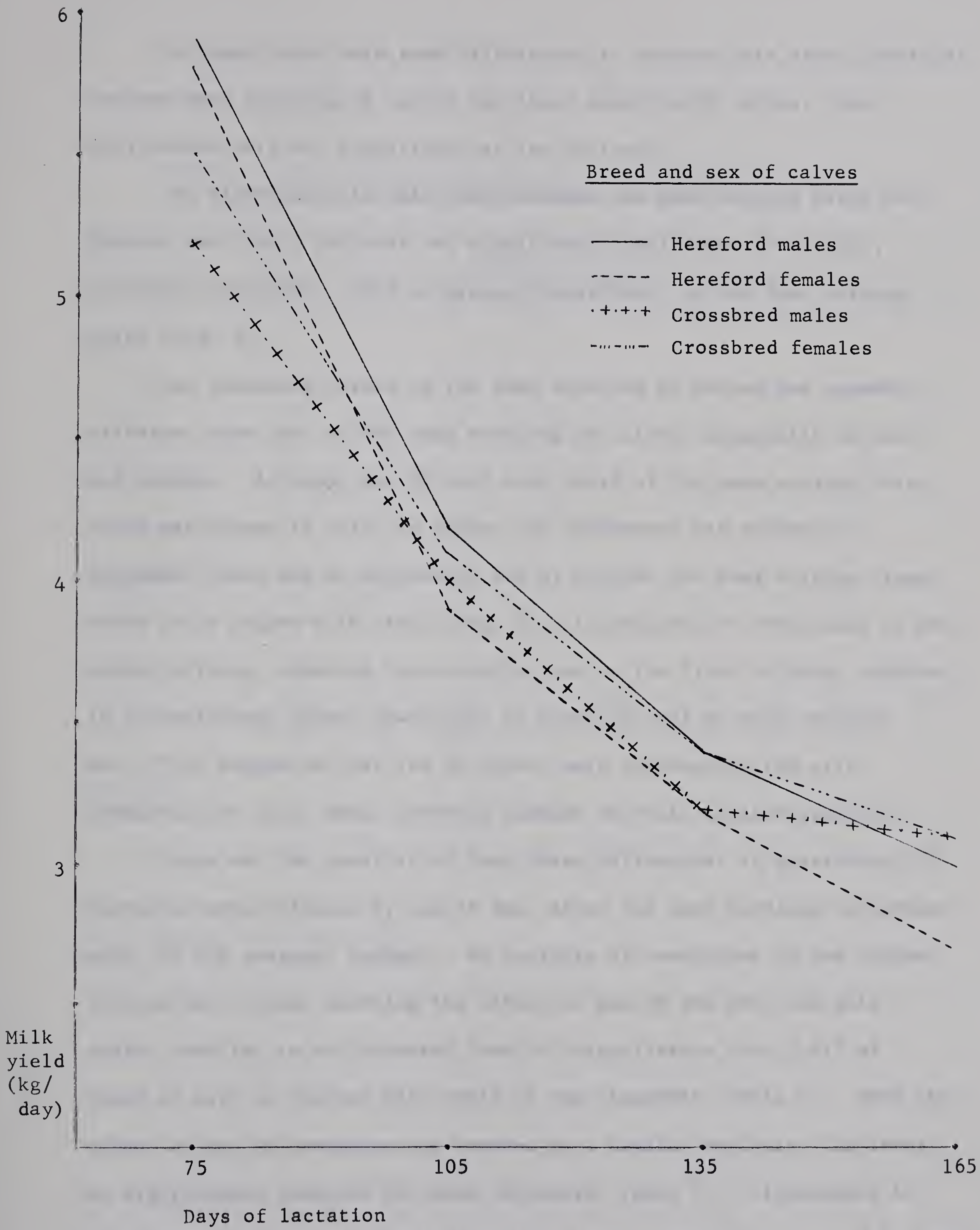
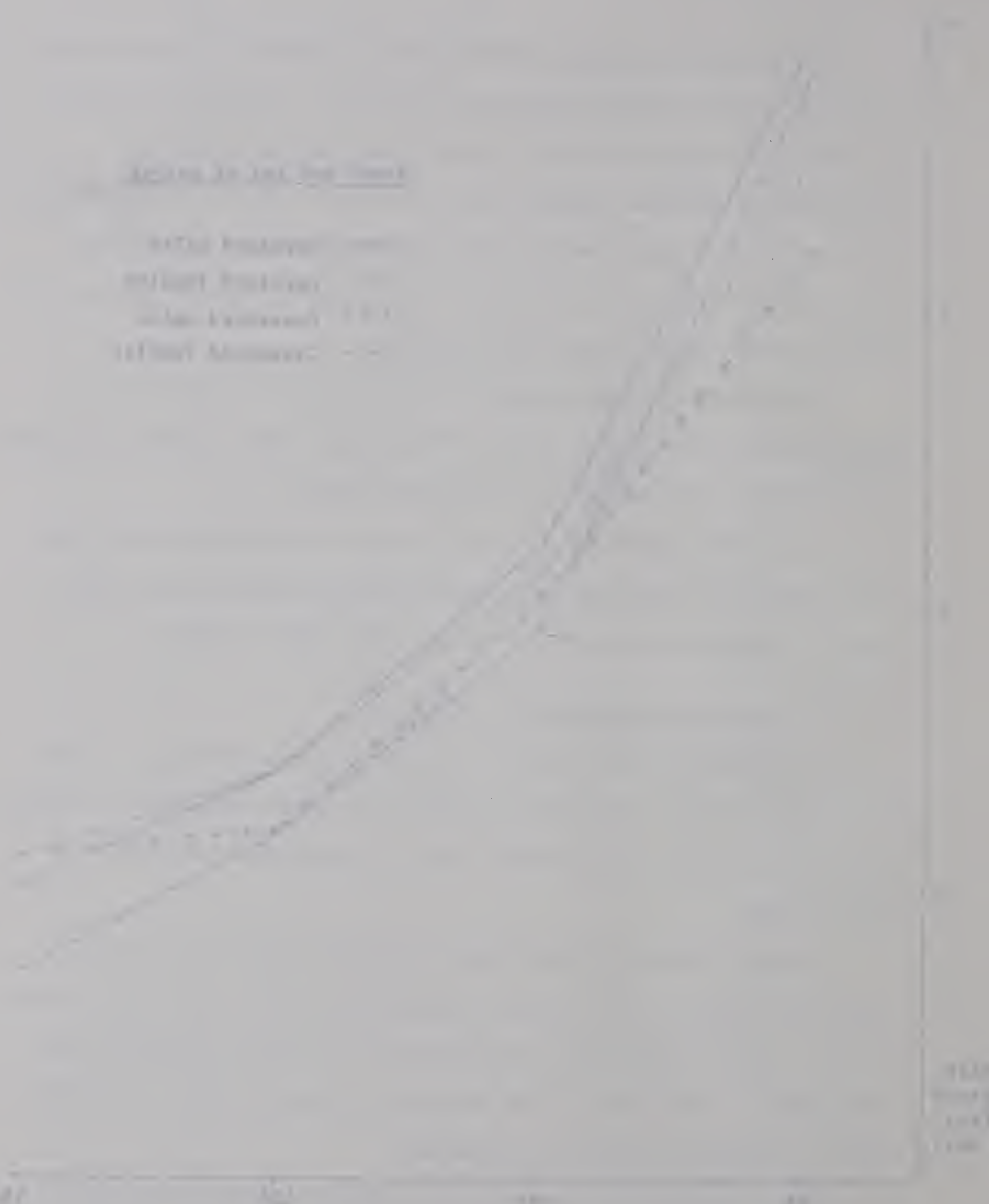


Figure 3. Lactation curves of the cows separated into breed-sex groups of calves



Although there were some differences in average milk yield (Table 8) between dams suckling HE calves and those suckling XB calves, these differences were not significant at the 5% level.

The differences in milk yield between the dams nursing males and females were small and were not significantly different ($P \lessdot 0.05$), although there was a trend to greater persistency in the dams nursing males (Fig. 4).

The lactation curves of the dams suckling HE calves was somewhat different from that of the dams suckling XB calves, especially in June and October. Although the 24-hour milk yield of the dams nursing Herefords was higher in July, in August the difference was minimal, in September there was no difference and by October the dams nursing crossbreds had a higher milk yield (Fig. 5). An analysis of covariance on the fourth milking, removing the variation due to the first milking, resulted in a significant effect ($P \lessdot 0.05$) of breed of calf on milk yield of dam. This suggested that the XB calves were influencing the milk production of their dams, probably because of their greater appetite.

There was the possibility that these differences in persistency of lactation were affected by age of dam, since the dams suckling crossbreds were, on the average, younger. An analysis of covariance on the October 24-hour milk yield, removing the effect of age of dam and June milk yield, resulted in an increased level of significance ($P \lessdot 0.01$) of breed of calf on October milk yield of dam (Appendix, Table 7). When the effect of day of lactation was removed by a similar analysis, the level of significance remained the same (Appendix, Table 7). Differences in persistency of milk yield were therefore independent of the age of dam and day of lactation.

Table 8. Means and standard deviations of milk yield for 40 cows according to breed-sex groups of calves

Milk yield (kg/day)	Groups of calves								
	HE-M	HE-F	XB-M	XB-F	HE	XB	M	F	Total
July									
Mean	5.9	5.8	5.2	5.5	5.8	5.4	5.5	5.6	5.6
SD	1.5	1.3	1.7	1.3	1.3	1.5	1.6	1.3	1.4
August									
Mean	4.2	3.9	4.0	4.1	4.1	4.0	4.1	4.0	4.1
SD	1.2	0.8	1.2	0.9	1.0	1.0	1.2	0.9	1.0
September									
Mean	3.4	3.2	3.2	3.4	3.3	3.3	3.3	3.3	3.3
SD	0.9	0.4	1.1	0.9	0.7	1.0	1.0	0.7	0.8
October									
Mean	3.0	2.7	3.1	3.1	2.8	3.1	3.1	2.9	3.0
SD	0.8	0.5	1.0	0.8	0.7	0.8	0.9	0.7	0.8
Average[1]									
Mean	4.1	3.9	3.9	4.0	4.0	3.9	4.0	3.9	4.0
SD	1.0	0.7	1.2	0.9	0.8	1.0	1.1	0.8	0.9

1 average of four milkings

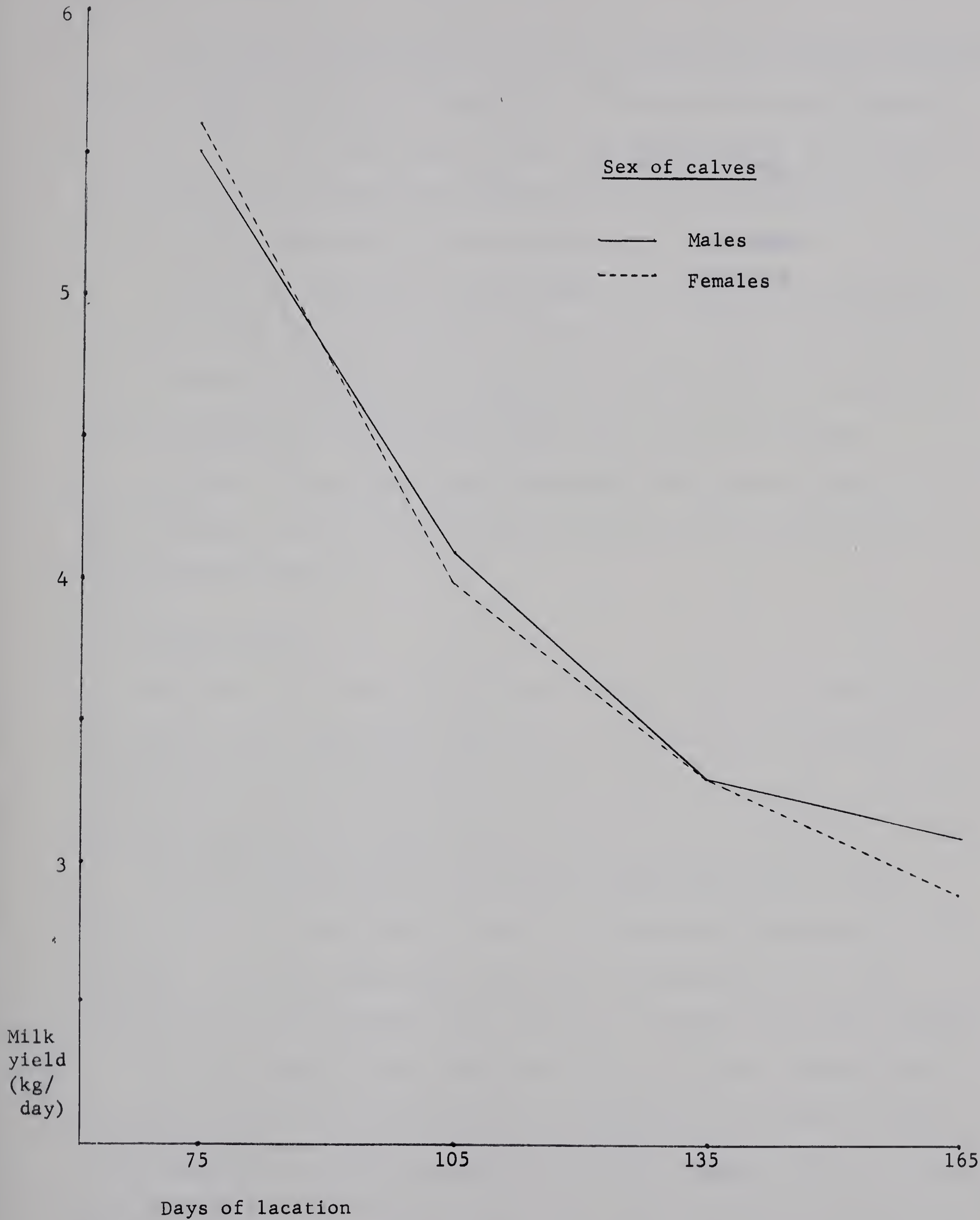


Figure 4. Lactation curves of dams separated according to the sex of calves

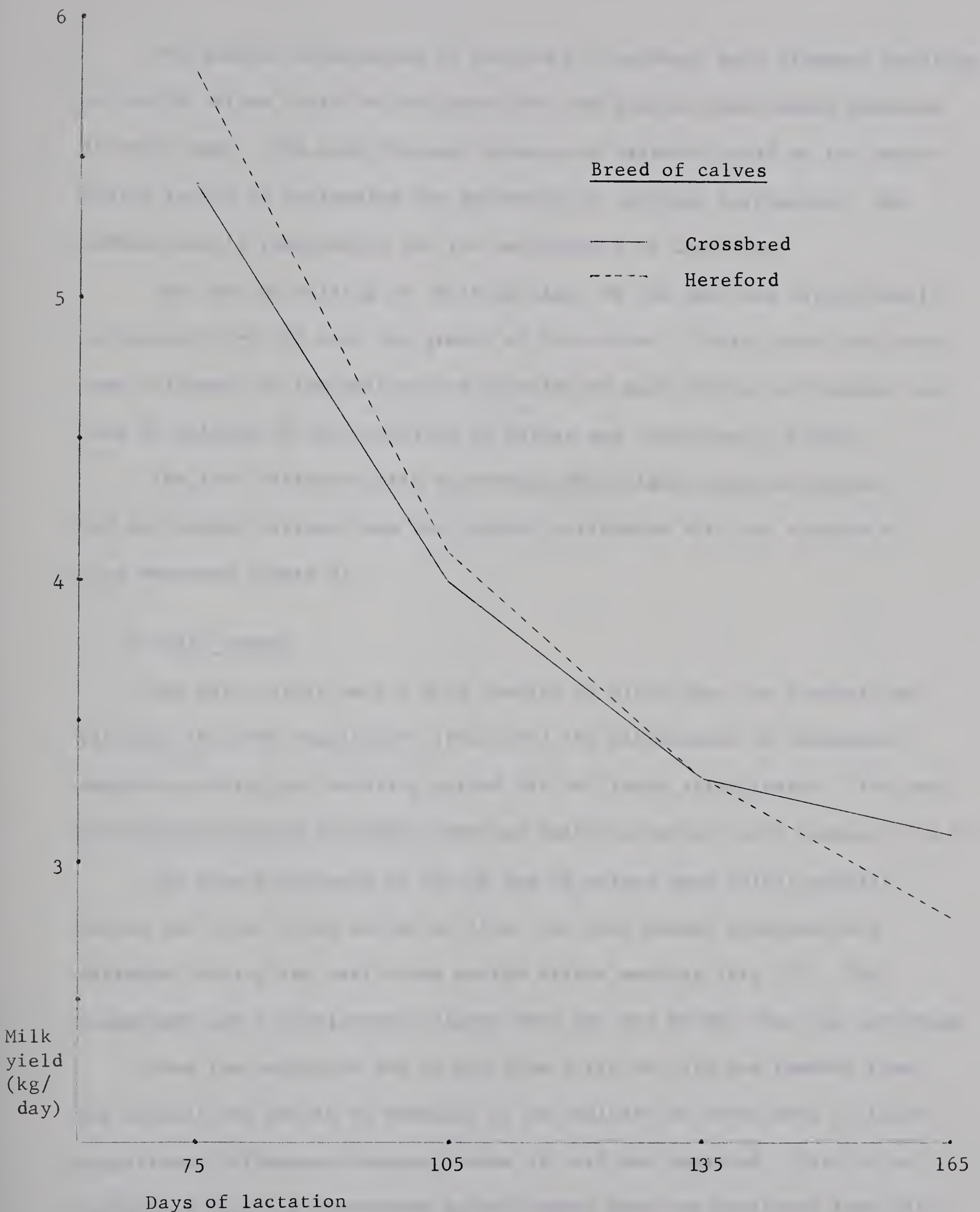


Figure 5. Lactation curves of cows separated according to breed of calf

The greater stimulation of the cow by, perhaps, more frequent suckling of the XB calves could be the reason for the greater persistency detected in their dams. The more frequent release of oxytocin could be the determining factor in increasing the secretion of lactogen (prolactin), the hormone mainly responsible for the maintenance of lactation.

The rate of milking or 'milking ease' of the dams was significantly correlated (r=0.39) with the growth of the calves. There could have been some influence of the calf on the ejection of milk by the cow because the rate of milking of cows suckling XB calves was consistently higher.

The four different milk recordings were highly intercorrelated and any single estimate was very highly correlated with the average of four measures (Table 9).

C. Calf growth

The male calves were 4.0 kg heavier at birth than the females, and although this was significant ($P < 0.05$) the differences in subsequent weighings during the suckling period did not reach significance. The mean differences between the sexes remained fairly constant until weaning (Fig.6).

The growth patterns of the HE and XB calves were fairly similar during the first three months of life, but they became progressively different during the next three months before weaning (Fig. 7). The crossbreds had a consistently higher mean ADG and wt/day than the purebreds.

When the variation due to ADG from birth to July was removed from the overall ADG (birth to weaning) by an analysis of covariance a highly significant difference between breeds of calf was detected. This is an indication that the crossbreds gained faster than the Herefords from July to October (Appendix, Table 4, 5 and 9).

Table 9. Intercorrelations of milk yield at different stages in the lactation period

Milk yield	Milk yield July	August	September	October	Average[1]
July		0.82	0.74	0.74	0.92
August			0.82	0.83	0.94
September				0.90	0.91
October					0.92

1 average of four recordings

$r = 0.32$ significant at $P < 0.05$
$r = 0.42$ significant at $P < 0.01$

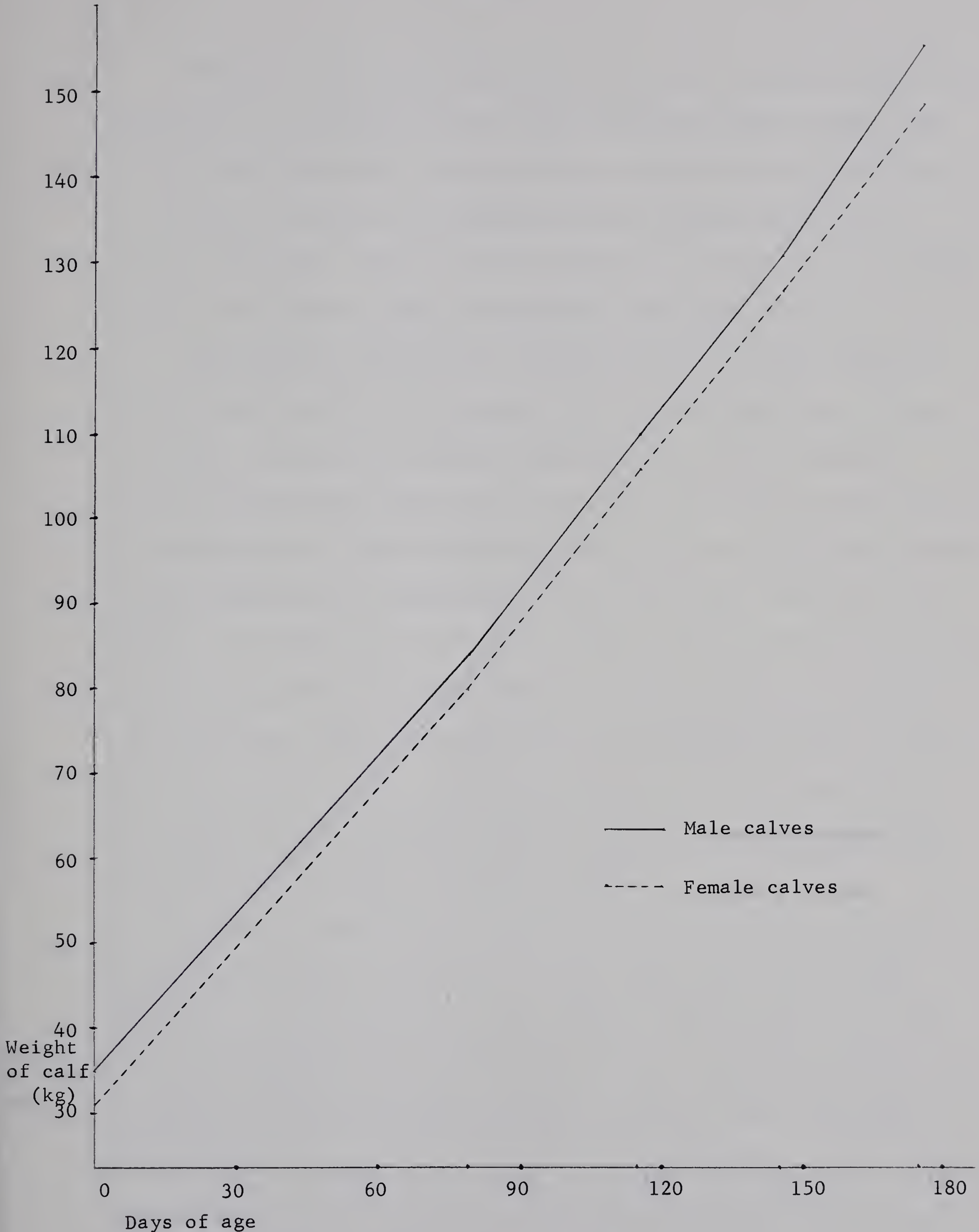


Figure 6. Growth curves of male and female calves

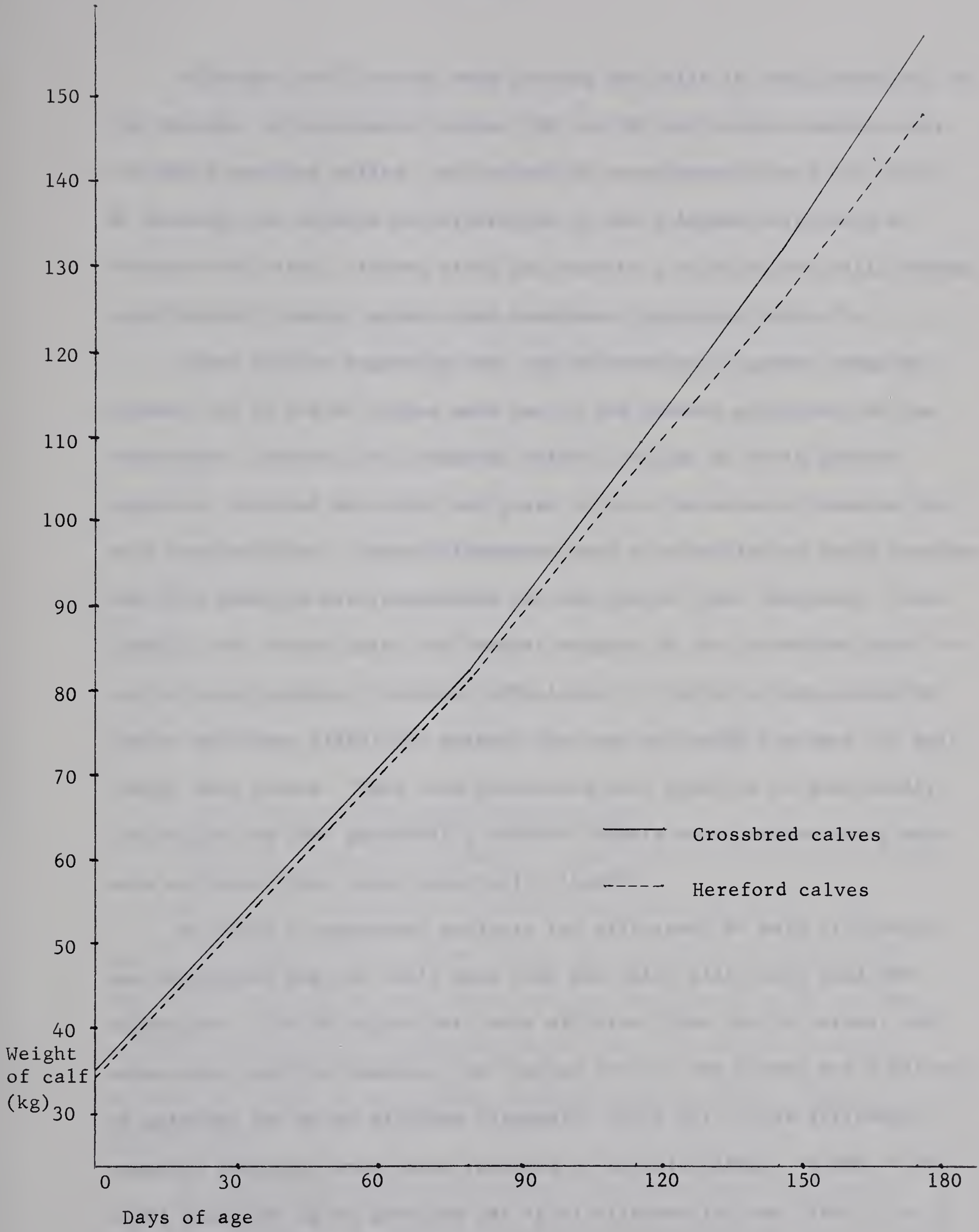


Figure 7. Growth curves of crossbred and Hereford calves

Although the XB calves were getting more milk in late lactation, on the average, both groups of calves (HE and XB) got similar amounts over the whole suckling period. Adjustment by covariance of calf ADG (birth to weaning) for effects of differences in dam's August milk yield or average milk yield, did not alter the results i.e. XB calves still showed significantly greater growth than Herefords (Appendix, Table 9).

These results suggested that the differences in growth observed between the XB and HE calves were due to the greater efficiency of the crossbreds. Whether the crossbred calves, because of their greater appetite, consumed more milk and grass in late lactation or because they were more efficient, these differences were a reflection of their genotype and this genotype was responsible for the hybrid vigor observed. Consequently, the faster gains and heavier weights of the crossbreds could be due to their greater 'intrinsic efficiency'. This is a term coined by Taylor and Young (1964) for animals that eat and weigh the same but gain faster than others. They also determined that appetite is genetically controlled and that genetically heavier animals were intrinsically much more efficient than those genetically lighter.

By using a regression analysis the efficiency of milk utilization was calculated and the daily gain (kg) per daily milk yield (kg) was determined. The XB calves were more efficient than the HE calves, the males more than the females; the average for all the calves was 0.075 kg of gain/day per kg of milk/day (Appendix, Table 10). This efficiency compares favorably with those reported by Neville (1962): 0.068, 0.051, 0.043 and 0.049 kg of gain/day per kg of milk/day for the first 2, 4, 6 and 8 months of age, respectively.

Efficiency can also be expressed as the amount of milk needed for 1 kg of gain. The crossbreds used 11.9 and the Herefords 15.2 kg of milk per kg of gain. Drewry et al. (1959) found 12.5 kg of milk per kg of gain were needed in the first month, 10.8 kg in the third and 6.3 kg in the sixth. Calves suckling heavier milkers were less efficient as they made least gain from milk. Bechdel (1917) reported an efficiency of 9.4 kg of milk per kg of gain. Lampkin and Lampkin (1960) determined in zebu cattle that 7.2 kg of milk per kg of gain were needed in the male calves and 7.9 kg in females. The efficiency of the calves in converting milk to live weight gain varies with the age and sex of calf.

The weight of the calf and wt/day at different stages during the suckling period were significantly correlated with the age of cow (range: 0.32 to 0.43), weight of cow (range: 0.37 to 0.55) and birth weight of calf (range: 0.55 to 0.68). These correlations suggest that older and heavier cows produced heavier calves at weaning time.

D. Relation of calf growth to milk yield

There was a close relationship between milk yield and ADG, wt/day or weight of calf throughout the suckling period (Table 10). The highest correlations were those between milk yield and wt/day (range from 0.45 to 0.81), although those with ADG (range from 0.40 to 0.80) are also fairly high. The relationships found are similar to those reported by Brumby et al. (1963), Gleddie (1965), Neville (1962) and Walker (1963).

The high correlations between milk yield in August and ADG or wt/day suggest that this milk yield is the best estimator of calf growth. Multiple regression analyses indicated that most of the variation in

Table 10. Correlations of ADG, wt/day and weight of calf with milk yields at different stages in lactation

	Milk yield				
	July	August	September	October	Average[1]
ADG					
B[2] - July	0.55	0.64	0.40	0.41	0.56
B - August	0.64	0.77	0.55	0.58	0.69
B - September	0.65	0.77	0.53	0.62	0.70
B - October	0.68	0.80	0.61	0.69	0.75
wt/day					
B - July	0.50	0.69	0.52	0.45	0.59
B - August	0.60	0.79	0.62	0.61	0.71
B - September	0.62	0.79	0.59	0.65	0.72
B - October	0.65	0.81	0.65	0.70	0.75
wt of calf					
July	0.41	0.46	0.31	0.30	0.41
August	0.49	0.57	0.43	0.44	0.53
September	0.52	0.59	0.43	0.49	0.55
October[3]	0.56	0.64	0.51	0.57	0.62

1 average of the four milk yields
2 birth
3 weaning weight

$r = 0.32$ significant at $P < 0.05$
$r = 0.42$ significant at $P < 0.01$

either measure of gain was associated with the August milk yield and that the inclusion of another measure of milk yield did not improve the prediction. After milk yield, the most important variable for predicting ADG was age of calf but this accounted for little variation (Table 11). Gleddie (1965) found that the average milk yield was a better predictor of calf growth than any single milking whereas in this study, a single milking was slightly superior. However, the differences in predictive value, comparing single and average yields in either study, were not large.

E. Relation of calf growth to milk composition

The lactation trends for protein, butterfat, SNF and TS were similar to those described by Gleddie (1965). There was an initial decrease in all milk constituents from July to August, but then a gradual rise with a sharp increase from September to October (Fig. 8).

Average milk constituent percentages ranged from 3.3 to 4.1%, 3.2 to 5.0%, 8.7 to 9.5% and 11.9 to 14.4% for protein, butterfat, SNF and TS, respectively (Appendix, Table 6).

The correlations of milk constituents with calf growth were mainly low and non-significant. Milk yield was negatively correlated with protein (range: 0.01 to -0.25), butterfat (range: 0.19 to -0.22) and SNF (range: -0.02 to -0.25).

The variation in milk constituents was relatively very small; this could be the explanation for the poor relationship with calf growth, since a correlation is a measure of the degree of simultaneous variation of two concomitant variables. A low relationship with calf growth has been reported previously by Gleddie (1965) and Klett et al. (1965).

Table 11. Ordered regressions of ADG (birth to weaning) and wt/day (birth to weaning) on milk yields, age of calf and age of cow

Dependent variable[1]	Independent variable (s)[2]	a[3]	b[4]	SE[5]	CD[6]
ADG 4		0.241			
	Y2		0.085**	0.015	63.90
	ACF		0.002*	0.001	4.51
	Y3		-0.013	0.018	0.45
WT/DAY 4		0.418			
	Y2		0.094**	0.019	64.96
	ACF		0.001	0.001	0.93
	ACW		0.009	0.008	0.91
	Y3		-0.016	0.024	0.42

1 ADG 4, average daily gain from birth to weaning; WT/DAY 4, weight per day of age from birth to weaning

2 Y2, milk yield in August; ACF, age of calf; ACW, age of cow; Y3, milk yield in September

3 a, interception of the ordinate

4 b, regression coefficient

5 SE, standard error of regression

6 CD, coefficient of determination (r^2 x 100)

* significant at $P \leq 0.05$
** significant at $P \leq 0.01$

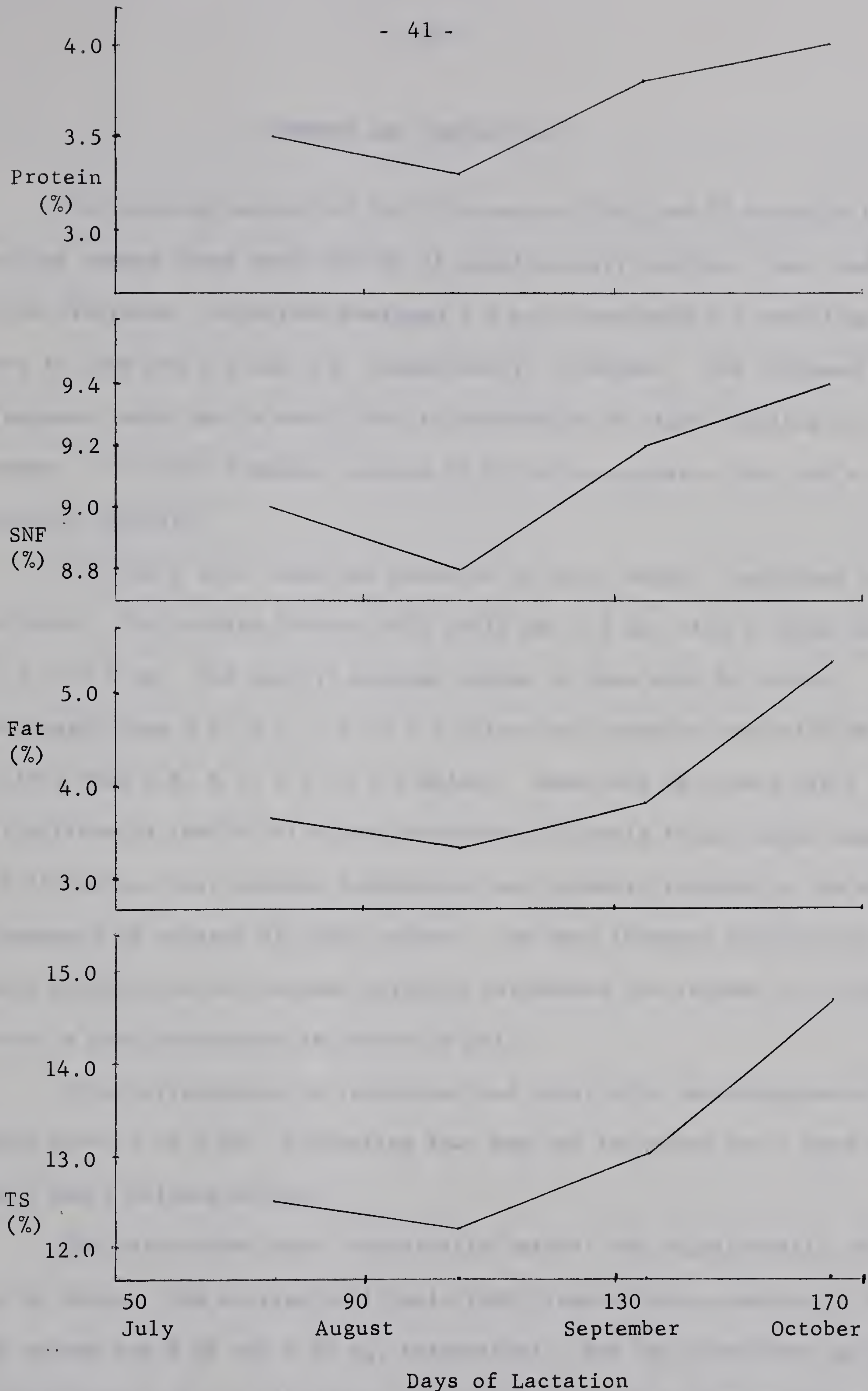


Figure 8. Lactation trends of protein, SNF, butterfat and TS

SUMMARY AND CONCLUSIONS

The nursing pattern of the 20 crossbred (XB) and 20 Hereford (HE) calves showed three peak periods of suckling:early morning, noon and late afternoon. Purebreds averaged 3.1 and crossbreds 3.4 sucklings per day in June and 3.6 and 3.8, respectively, in August. The increase in frequency with age is mostly due to recordings of night suckling in August. The more frequent nursing by XB calves suggests they had a greater appetite.

The dam's milk yield was measured in July, August, September and October. The average 24-hour milk yield was 4.0 kg, with a range from 2.3 to 6.0 kg. The monthly average yields of dams with XB calves decreased from 5.4, 4.0, 3.3 to 3.1 kg/day and those for dams with HE calves from 5.8, 4.1, 3.3 to 2.8 kg/day. Dams with XB calves had a significantly ($P \leq 0.01$) higher adjusted milk yield in the later stages of lactation; this greater persistency was probably related to the higher frequency of nursing of their calves. The more frequent stimulation of milk ejection could, because oxytocin influences the release of lactogen, cause a more persistent secretion of milk.

Intercorrelations of individual and total milk recordings were very high (r=0.74 to 0.94), indicating that any one recording was a good estimate of a cow's milking ability.

The male calves were consistently heavier and significantly ($P \leq 0.05$) so at birth. The average daily gain (ADG) from birth to weaning of XB and HE calves was 0.69 and 0.65 kg, respectively, and the crossbreds gained significantly ($P \leq 0.01$) faster in the later stages of the period. Since both groups of calves got similar amounts of milk over the whole suckling

period, the XB calves either ate more or were more efficient or both.

The efficiency of milk utilization of the XB calves was higher; they used 11.9 kg of milk per kg of gain, whereas the HE calves needed 15.2 kg.

All measures of milk yield were highly correlated with ADG (r=0.40 to 0.80); thus, the use of one recording accounted for most of the variation when predicting ADG.

The percentages of protein, butterfat, solids-not-fat and total solids ranged from 3.3 to 4.1%, 3.2 to 5.0%, 8.7 to 9.5% and 11.9 to 14.4%, respectively. All milk constituents decreased initially, but then rose gradually with a sharp increase in late lactation. Average milk constituents were not useful in predicting ADG because of their low correlations with calf gains.

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APPENDIX

Table 1. Birth date and age of dam of Hereford and crossbred calves

Hereford			Crossbred		
Birth date	Calf brand	Age of dam (years)	Birth date	Calf brand	Age of dam (years)
		Males			
April 1	1	4	April 3	207	5
7	9	3	6	212	6
12	15	5	12	233	7
14	18	6	12	234	7
14	19	5	16	244	3
16	25	6	16	249	3
26	29	9	23	251	6
26	32	5	25	252	3
May 3	37	5	30	264	5
11	40	6	May 9	282	3
		Females			
April 1	2	6	April 1	206	2
1	5	6	4	226	2
6	6	4	6	221	5
7	8	6	7	223	3
9	13	6	8	229	6
13	17	3	10	237	2
24	28	6	26	253	5
26	31	5	27	255	5
May 2	36	2	May 2	275	3
5	39	4	3	271	6

Table 2. Frequency of nursing of the two breeds of calves

Hereford				Crossbred			
Cow brand[1]	Calf brand	June[2]	August[3]	Cow brand	Calf brand	June	August
			Males				
44-1	1	4	3	9-0	207	5	5
27-2	9	3	2	16-9	212	4	2
14-0	15	2	3	125-8	233	3	3
8-9	18	3	4	133-8	234	2	3
3-0	19	3	3	43-2	244	2	4
150-9	25	3	4	45-2	249	4	3
5-6	29	4	5	70-9	251	4	4
10-0	32	3	4	20-2	252	4	5
8-0	37	2	5	1-0	264	3	4
170-9	40	5	4	34-2	282	3	4
			Females				
017-9	2	2	3	13-3	206	2	3
59-9	5	2	2	9-3	226	3	5
50-1	6	3	4	33-2	221	4	3
2-9	8	4	4	03-9	223	3	3
37-9	13	4	4	15-0	229	3	2
21-2	17	3	3	23-3	237	4	3
75-9	28	3	3	12-0	253	4	5
013-0	31	3	3	16-0	255	5	5
1-3	36	3	4	2-2	275	4	5
27-1	39	3	4	92-9	271	3	4

1 -6, born 1956; -8, born 1958; -9, born 1959; -0, born 1960; -1, born 1961; -2, born 1962; -3, born 1963

2 observations on June 24 - 25

3 observations on August 31 - September 1

Table 3. Twenty-four hour milk yield for 40 cows

Cow brand	Breed and sex of calf[1]	24-hour milk yield (kg) July	August	September	October	Average[2]
44-1	HE-M	5.6	3.5	2.5	2.1	3.4
27-2		6.3	4.2	3.0	3.1	4.1
14-0		6.8	4.0	3.2	3.1	4.3
8-9		7.3	5.5	4.5	4.1*	5.3
3-0		3.2	3.2	2.9	1.9	2.8
150-9		5.7	3.3	2.7	2.6	3.6
5-6		6.8	5.1	4.5	3.7	5.0
10-0		4.5	3.2	2.6	2.5	3.2
8-0		4.4	3.5	3.5	3.0	3.6
170-9		8.0	6.8	4.8	4.3	6.0
017-9	HE-F	3.9	3.7	2.9	2.3	3.2
59-9		6.4	4.2	3.5	3.6	4.4
50-1		6.8	4.5	2.7	2.7	4.2
2-9		4.4	3.3	2.8	2.4	3.2
37-9		5.0	2.7	2.7	2.2*	3.1
21-2		7.4	3.8	3.4	2.3	4.2
75-9		5.0	3.5	3.1	2.6	3.5
013-0		5.0	3.5	3.4	2.6	3.6
1-3		6.1	4.6	3.4	2.6	4.2
27-1		7.5	5.6	4.1	3.5*	5.2
9-0	XB-M	6.7	5.0	4.7	4.1	5.1
16-9		6.4	5.4	4.6	4.7	5.3
125-8		6.4	5.2	3.8	3.7	4.8
133-8		7.6	4.4	3.8	3.6*	4.8
43-2		4.7	3.4	3.2	3.0	3.6
45-2		3.7	3.2	2.0	2.0	2.7
70-9		6.6	5.3	4.2	3.2	4.8
20-2		3.2	2.3	1.8	1.9	2.3
1-0		3.5	3.2	2.3	2.4	2.8
34-2		3.5	2.5	2.0	2.1	2.5
13-3	XB-F	4.9	3.2	2.7	2.1	3.2
9-3		5.9	3.5	2.9	3.0	3.8
33-2		4.4	4.4	2.0	2.2	3.2
03-9		5.1	4.1	4.1	3.4	4.2
15-0		5.9	4.4	3.5	3.2	4.2
23-3		4.2	3.3	2.7	2.4	3.1
12-0		7.4	5.3	5.0	4.5	5.5
16-0		8.1	6.0	4.0	4.1	5.5
2-2		5.3	3.6	3.0	3.2	3.8
92-9		4.2	3.5	3.6	3.2	3.6

1 HE, Hereford; XB, crossbred; M, males; F, females
2 average of four milkings
* estimated milk yield

Table 4. ADG of breed-sex groups of calves at different stages during the suckling period

Breed and sex	Calf brand	ADG (kg/day)							
		B[1] - July		B - August		B - September		B - October	
HE-M	1	0.63		0.66		0.69		0.67	
	9	0.67		0.74		0.72		0.75	
	15	0.62		0.66		0.67		0.67	
	18	0.63		0.72		0.72		0.73	
	19	0.59		0.66		0.62		0.62	
	25	0.50		0.59		0.59		0.63	
	29	0.62		0.64		0.64		0.64	
	32	0.43		0.47		0.49		0.56	
	37	0.50		0.56		0.53		0.58	
	40	0.79	0.60[a]	0.93	0.66	0.85	0.65	0.83	0.67
			(0.10)		(0.12)		(0.10)		(0.08)
HE-F	2	0.66		0.68		0.64		0.63	
	5	0.65		0.70		0.71		0.70	
	6	0.71		0.72		0.70		0.70	
	8	0.46		0.54		0.53		0.54	
	13	0.50		0.54		0.56		0.55	
	17	0.39		0.51		0.54		0.56	
	28	0.53		0.60		0.61		0.62	
	31	0.62		0.64		0.60		0.63	
	36	0.52		0.58		0.56		0.60	
	39	0.77	0.58	0.74	0.62	0.68	0.62	0.72	0.62
			(0.12)		(0.08)		(0.07)		(0.06)
XB-M	207	0.52		0.64		0.64		0.70	
	212	0.63		0.77		0.77		0.82	
	233	0.77		0.80		0.81		0.81	
	234	0.75		0.77		0.75		0.80	
	244	0.51		0.58		0.59		0.65	
	249	0.62		0.62		0.64		0.65	
	251	0.81		0.80		0.78		0.85	
	252	0.32		0.39		0.45		0.45	
	264	0.54		0.61		0.62		0.58	
	282	0.49	0.60	0.53	0.66	0.58	0.66	0.60	0.69
			(0.15)		(0.14)		(0.11)		(0.13)
XB-F	206	0.78		0.74		0.73		0.72	
	226	0.53		0.61		0.64		0.64	
	221	0.54		0.62		0.65		0.71	
	223	0.48		0.61		0.67		0.73	
	229	0.66		0.76		0.72		0.72	
	237	0.50		0.57		0.54		0.54	
	253	0.62		0.66		0.69		0.74	
	255	0.71		0.79		0.89		0.83	
	275	0.52		0.60		0.64		0.68	
	271	0.39	0.57	0.51	0.65	0.54	0.67	0.56	0.69
			(0.12)		(0.09)		(0.10)		(0.09)

1 B, birth

a average; standard deviation in parentheses

Table 5. Wt/day of breed-sex groups of calves at different stages during the suckling period

Breed and sex	Calf brand	wt/day (kg/day)							
		B[1] - July		B - August		B - September		B- October	
HE-M	1	0.95		0.90		0.88		0.83	
	9	0.94		0.94		0.88		0.88	
	15	0.99		0.93		0.88		0.85	
	18	1.10		1.06		0.99		0.95	
	19	1.02		0.96		0.86		0.82	
	25	0.90		0.88		0.81		0.81	
	29	1.09		0.96		0.89		0.85	
	32	0.90		0.79		0.74		0.77	
	37	1.03		0.92		0.80		0.80	
	40	0.45	1.04[a]	0.35	0.97	1.16	0.89	1.08	0.86
			(0.16)		(0.15)		(0.12)		(0.09)
HE-F	2	0.95		0.90		0.82		0.77	
	5	1.02		0.97		0.94		0.90	
	6	1.00		0.94		0.88		0.84	
	8	0.79		0.78		0.72		0.70	
	13	0.83		0.78		0.74		0.71	
	17	0.82		0.82		0.78		0.76	
	28	1.12		1.01		0.93		0.88	
	31	1.03		0.92		0.82		0.81	
	36	0.88		0.82		0.74		0.74	
	39	1.28	0.97	1.08	0.90	0.93	0.83	0.93	0.80
			(0.15)		(0.10)		(0.08)		(0.08)
XB-M	207	0.97		0.97		0.90		0.92	
	212	1.00		1.05		0.99		1.01	
	233	1.30		1.19		1.12		1.06	
	234	1.12		1.04		0.95		0.97	
	244	0.93		0.88		0.83		0.84	
	249	1.07		0.94		0.89		0.86	
	251	1.40		1.21		1.10		1.11	
	252	0.70		0.66		0.65		0.62	
	264	1.05		0.96		0.88		0.80	
	282	0.99	1.06	0.85	0.98	0.80	0.91	0.80	0.90
			(0.20)		(0.16)		(0.14)		(0.15)
XB-F	206	1.09		0.97		0.92		0.87	
	226	0.89		0.87		0.85		0.81	
	221	0.93		0.90		0.88		0.90	
	223	0.89		0.91		0.91		0.92	
	229	1.02		1.03		0.93		0.90	
	237	0.74		0.74		0.68		0.66	
	253	1.06		0.96		0.92		0.93	
	255	1.20		1.13		1.16		1.04	
	275	0.81		0.80		0.79		0.80	
	271	0.86	0.95	0.83	0.91	0.78	0.88	0.75	0.86
			(0.14)		(0.11)		(0.13)		(0.11)

1 B, birth

a average; standard deviation in parentheses

Table 6. Milk composition averages for 40 cows

Cow brand	Breed and sex of calf	Constituent percentages			
		Protein	Fat	SNF	TS
44-1	HE-M	3.8	4.8	9.3	14.1
27-2		3.5	3.9	9.1	13.0
14-0		3.5	4.2	8.9	13.1
8-9		3.8	4.3	9.0	13.3
3-0		3.8	4.0	9.2	13.2
150-9		3.9	4.1	9.1	13.2
5-6		3.4	3.8	9.0	12.8
10-0		3.9	4.6	9.5	14.1
8-0		3.6	4.1	9.2	13.3
170-9		3.6	4.6	9.1	13.7
017-9	HE-F	3.7	4.0	9.0	13.0
59-9		3.8	3.3	9.1	12.4
50-1		3.8	5.0	9.4	14.4
2-9		3.8	3.6	9.1	12.8
37-9		3.5	3.8	9.0	12.8
21-2		3.9	3.8	9.2	13.0
75-9		3.3	3.8	8.9	12.8
013-0		3.9	4.0	9.1	13.1
1-3		3.4	4.0	9.0	13.0
27-1		3.5	4.0	9.1	13.1
9-0	XB-M	3.6	4.0	9.0	13.0
16-9		3.4	3.3	9.1	12.4
125-8		3.6	5.0	9.4	14.4
133-8		4.1	3.6	9.1	12.8
43-2		3.6	3.8	9.0	12.8
45-2		3.5	3.8	9.2	13.0
70-9		3.7	3.8	8.9	12.8
20-2		3.8	4.0	9.1	13.1
1-0		3.5	4.0	9.0	13.0
34-2		3.7	4.0	9.1	13.1
13-3	XB-F	3.7	4.0	9.3	13.3
9-3		3.3	3.2	8.7	11.9
33-2		4.0	4.5	9.3	13.8
03-9		3.5	4.4	9.3	13.7
15-0		3.5	4.3	8.9	13.2
23-3		3.5	3.3	8.9	12.2
12-0		3.5	3.4	8.9	12.3
16-0		3.8	4.1	9.2	13.3
2-2		3.4	3.6	8.7	12.3
92-9		3.5	3.8	9.1	12.9

Table 7. Mean squares from analyses of covariance of October milk yield

Dependent variable[1]	Independent variable(s)[2]	Source of variation[3]	Degrees of freedom[4]	Mean squares
Y4	Y1	Breed	1	1.7147*
		Sex	1	0.3705
		BxS	1	0.1444
		Error	31	0.2592
Y4	ACW,Y1	Breed	1	2.5378**
		Sex	1	0.0398
		BxS	1	0.2384
		Error	30	0.1855
Y4	ACW,DL,Y1	Breed	1	2.5628**
		Sex	1	0.0176
		BxS	1	0.2296
		Error	29	0.1775

1 Y4, October milk yield (4th milking)
2 Y1, July milk yield; ACW, age of cow; DL, day of lactation
3 Breed, breed of calf; Sex, sex of calf; BxS, breed x sex interaction
4 Error degrees of freedom, 35, looses 4 because of missing values

* Significant at $P < 0.05$
** Significant at $P < 0.01$

Table 8. Mean squares from analysis of variance of birth weight

Source of variation[1]	Degrees of freedom	Mean squares
Breed	1	8.6828
Sex	1	154.5919*
BxS	1	35.5836
Error	36	30.5756

* Significant at $P < 0.05$
1 Breed, breed of calf
Sex, sex of calf
BxS, breed x sex interaction

Table 9. Mean squares from analysis of covariance of ADG from birth to weaning

Dependent variable[1]	Independent variable[2]	Source of variation	Degrees of freedom	Mean squares
ADG 4	ADG 1	Breed	1	0.02209**
		Sex	1	0.00109
		BxS	1	0.00494
		Error	35	0.00236
ADG 4	Y2	Breed	1	0.02026*
		Sex	1	0.00312
		BxS	1	0.00022
		Error	35	0.00284
ADG 4	YM	Breed	1	0.02312*
		Sex	1	0.00361
		BxS	1	0.00031
		Error	35	0.00342

1 ADG 4, ADG from birth to weaning
2 ADG 1, ADG from birth to July; Y2, August milk yield; YM, average of four milk yields

* significant at $P < 0.05$
** significant at $P < 0.01$

Table 10. Regressions of ADG (B-weaning) on milk yield to determine the efficiency of the breed-sex groups

Breed-sex group[1]	Milk yield[2] (August)	Milk yield[3] (average)	Efficiency[4] (kg/day per kg/day)
Hereford-males			
a	0.432	0.413	
b	0.056**	0.062**	0.062
SE	0.014	0.018	
CD	68.44	60.00	
Hereford-females			
a	0.387	0.359	
b	0.060*	0.069*	0.069
SE	0.019	0.024	
CD	57.05	50.01	
Crossbred-males			
a	0.304	0.330	
b	0.097**	0.093**	0.093
SE	0.015	0.018	
CD	83.00	77.22	
Crossbred-females			
a	0.386	0.419	
b	0.073*	0.067*	0.067
SE	0.021	0.026	
CD	60.09	45.76	
Hereford			
a	0.404	0.381	
b	0.059**	0.066**	0.066
SE	0.010	0.014	
CD	63.79	56.39	
Crossbred			
a	0.334	0.360	
b	0.088**	0.084**	0.084
SE	0.012	0.015	
CD	73.98	65.36	
Males			
a	0.374	0.369	
b	0.074**	0.078**	0.078
SE	0.011	0.013	
CD	69.86	65.56	

Table 10 continued

Females			
a	0.370	0.377	
b	0.071**	0.071**	0.071
SE	0.015	0.018	
CD	55.06	43.92	
Total[5]			
a	0.368	0.367	
b	0.074**	0.075**	0.075
SE	0.009	0.010	
CD	63.90	56.92	

1 a, interception of the ordinate
b, regression coefficient
SE, standard error of the regression coefficient
CD, coefficient of determination ($r^2 \times 100$)

2 milk yield from second milking

3 average of four milkings

4 kg of gain/day per kg of milk/day

5 includes all calves

* significant at $P < 0.05$
** significant at $P < 0.01$